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Progress and Prospect of Wild Germplasm Conservation

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Abstract

Genetic resources are important strategic resources for the national interest, security, and sustainable economic and social development of a country. Wild germplasm with their great potential in bio-industry applications, received wide attention globally, specifically in wild plant preservation. China has achieved great progress in the infrastructure building and preservation of wild germplasm. This study suggests that it is crucial to develop China's national strategy of wild germplasm preservation by improving the top-down design and overall planning, other suggestions include enhancing the survey and collection projects of wild species and the evaluation of germplasm traits; enforcing and implementing laws and regulations on biological resources protection; promoting cooperation and joint work plans on germplasm management and regulation enforcement; talent and team building to strengthen the germplasm facilities management and operation; increasing the input on fundamental research and the development of technical standards, and arising the public awareness on germplasm conservation through training programmes.

Keywords

biological diversity; germplasm; genetic resources; conservation

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Progress and Prospect of Wild Germplasm Conservation

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Abstract: Genetic resources are important strategic resources for the national interest, security, and sustainable economic and social development of a country. Wild germplasm with their great potential in bio-industry applications, received wide attention globally, specifically in wild plant preservation. China has achieved great progress in the infrastructure building and preservation of wild germplasm. This study suggests that it is crucial to develop China's national strategy of wild germplasm preservation by improving the top-down design and overall planning, other suggestions include enhancing the survey and collection projects of wild species and the evaluation of germplasm traits; enforcing and implementing laws and regulations on biological resources protection; promoting cooperation and joint work plans on germplasm management and regulation enforcement; building talent team to strengthen the management and operation of germplasm facilities; increasing the input on fundamental research and the development of technical standards, and raising the public awareness on germplasm conservation through training programs. **DOI:** 10.16418/j.issn.1000-3045.20210302001-en

Keywords: biological diversity; germplasm; genetic resources; conservation

According to the definition by the Convention on Biological Diversity, genetic resources are genetic materials of practical or potential value, including any material of plant, animal, microbial or other origin containing functional units of heredity. Genetic resources undergo long-term natural selection and mutation, providing humans with food, energy, medicine, and entertainment and serving as a basis for the survival and development of human society. The term "germplasm" appeared before the popularization of Mendelian genetics and refers to the genetic material passed from parents to offspring. According to the "continuity of germplasm" theory proposed by the German biologist Weismann, germplasm can be transmitted across generations by germ cells. Therefore, germplasm is sometimes used as a synonym for genetic resources in a narrow sense.

In this paper, germplasm is defined as the genetic resources with vitality or reproductivity. With the rapid development of modern agriculture and biotechnology, using germplasm to improve the traits and qualities of animals and plants provides potential solutions for major problems in food, health, and environment sectors. Compared with cultivated plants and domesticated animals, wild germplasm has long lived in natural habitats (wild environment) and received less attention, and their value largely remains undiscovered. Some of them are close relatives or wild ancestors of crops and domesticated animals, and retain the elite traits lost during the artificial selection, such as disease resistance in domesticated animals, and resistance to pests, diseases, and abiotic stresses (e.g., extreme conditions, drought, and flooding) in crops. A full understanding of elite traits in wild germplasm and gene mining will greatly benefit the innovation in seed industry.

With the aggravation of the influences of human activities and climate changes on global environment, the habitats of many wild animals and plants have been destroyed. Wild germplasm is facing an unprecedented crisis that threatens the sustainable development of human society. With the advances in biotechnology, germplasm has become an important strategic resource of a country and a measure of comprehensive national strength that determines national sovereignty and security. In December 2020, the Central Economic Work Conference of China included seed and arable land issue as one of the eight key tasks for 2021. The Conference specified the necessity to strengthen the protection and utilization of germplasm and the construction of seed bank, to study the technologies that strangle the development of seed sources, and to fight for a better seed industry. Germplasm is not only the source for the development of seed industry but also the basis for the sustainable development of human society. The development of proper germplasm conservation strategies can enhance the protection, maintenance, and sustainable use of biodiversity, which is associated with national economic development and social stability [1].

The year 2021 is the first year of the "Fourteenth Five-Year Plan" period and faces new situations and

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requirements in the economic and social development in China. Meanwhile, the 15th Conference of the Parties (COP15) of the United Nations Convention on Biological Diversity in Kunming will discuss the post-2020 global biodiversity framework. At this time point of multiple events, it is necessary to review and summarize the progress in wild germplasm in China, and on this basis to reflect and plan for the conservation and development of wild germplasm in China. This measure will provide scientific support for China's major breakthroughs of key technologies in ecological civilization, seed industry, and biotechnology, and contribute to the realization of China's grand blueprint of becoming a innovative country in 2035.

1 Current status of wild germplasm conservation

Biodiversity protection is closely related to wild germplasm conservation. Most of the policies, strategic plans, and action plans developed to strengthen biodiversity protection directly guide the management and conservation of wild germplasm. The strategies for wild germplasm conservation manifest the measures to protect biodiversity at the three levels of ecosystem, species, and population (heredity). Additionally, traditional knowledge is important in the practice of wild germplasm conservation, which is embodied in the human dimension of biodiversity conservation.

1.1 *In situ* and *ex situ* conservation of wild germplasm

In situ and *ex situ* conservation strategies are commonly used for wild germplasm. Theoretically, *in situ* conservation is the best strategy as it preserves not only the germplasm but also its ecosystem, habitat, and companion species, and maintains the services of ecosystem. However, with the intensifying human activities and global changes, *in situ* conservation suffers from problems like insufficient protection area, inadequate capacity, and the absence of key species in protected areas. In this case, *ex situ* conservation can be an alternate for the protection of wild species. Traditional *ex situ* conservation methods, such as botanical gardens, zoos, and germplasm nurseries, face challenges in improving the conservation performance for rare alleles, increasing the genetic diversity of species, and reducing the maintenance cost. Besides, these methods have difficulties in the conservation and reproduction of special germplasm (especially animals). Regular updating of such germplasm presents new scientific and technological challenges. Conservation of wild plant germplasm by seed banks with freeze-drying technique is considered to be the most cost-effective method of *ex situ* conservation [2]. For animals, frozen sperm/embryos or cryopreserved primary cells obtained from isolation and cultivation can also be used for germplasm conservation.

1.2 Progress of wild germplasm conservation worldwide

At the beginning of the 20th century, many countries attached great importance to the collection of crop germplasm. In the 21st century, many developed countries further put focus on the collection, conservation, evaluation, exploration, and utilization of wild germplasm. Taking plants as an example, more than 6 million germplasm accessions were stored in 1 750 seed banks worldwide at the end of 2020 [3]. Although most seed banks focus on crops, wild species account for a large portion in the 50 000–60 000 conserved plant species. The U.S. National Plant Germplasm System holds about 600 000 seed accessions of crop and wild plant germplasm belonging to 16 162 species. The Millennium Seed Bank of the Royal Botanical Gardens (Kew Gardens) has the largest number (39 681) of wild plant species and leads the collection and conservation of wild species closely related to crops around the globe. Supported by the 6th EU Research Framework Programme, 29 seed banks of European Union members jointly established the European Native Seed Conservation Network (ENSCONET), which collected and preserved 63 582 germplasm accessions of 11 515 wild plant species in European Union countries, including 75% of wild relatives of crops in the region [4]. Twelve regional seed banks and institutions in Australia constitute the Australian Seed Bank Partnership, which collect the germplasm of Australian species by means of seeds, tissue cultures, and cryopreservation to supplement the living germplasm in botanical gardens. In recent years, Asian countries have increased investment in the collection and preservation of wild germplasm. For instance, the Baekdudaegan Global Seed Vault that can accommodate 2 million seed accessions was established in 2018 in South Korea. To strengthen the collection of plant germplasm in Southeast Asia, Singapore built its first seed bank (Singapore Botanic Gardens Seed Bank) in 2019 with a capacity of 25 000 plant species. A national seed preservation facility is under construction in Thailand.

Livestock, poultry, and aquatic species with important economic values are conserved as animal germplasm. Wild animal germplasm is protected mainly through *in situ* conservation and occasionally through *ex situ* conservation. For example, the Frozen Zoo at the San Diego Zoo (California, the US) has collected and preserved more than 10 000 cell lines and sperm/egg cells from nearly 1 000 wild animal species since 1972. The Cincinnati Zoo (Ohio, the US) has conducted long-term preservation and research on endangered animal germplasm, and established good conservation systems for rhinoceros, polar bears, and felids.

1.3 Progress of wild germplasm conservation in China

As a party to the Convention on Biological Diversity, China has paid increasing attention to biodiversity protection since the 21st century, and established the China National

Committee for Biodiversity Conservation chaired by national leaders. The Chinese government issued the China National Biodiversity Conservation Strategy and Action Plan (2011–2030), which clarified the medium- and long-term strategic objectives, delineated priority regions for biodiversity protection, and determined a series of priority areas and actions for protection. Since the 18th National Congress of the Communist Party, China has included ecological civilization construction in the general development plan, proposed the vision of building a Beautiful China, and legalized the management of biodiversity. The government issued a series of regulations, established a number of conservation facilities, and promoted the sharing of resources and information.

(1) Policies and regulations. China has developed the management systems and measures for germplasm conservation, and enacted Wild Animal Conservation Law of the People's Republic of China, Seed Law of the People's Republic of China, Regulations of the People's Republic of China on Wild Plants Protection, Regulations of the People's Republic of China on Nature Reserves, and Biosecurity Law of the People's Republic of China. Strategic and action plans were developed according to the Global Strategy for Plant Conservation 2002–2010, 2011–2020. The Chinese government first released the China's Strategy for Plant Conservation 2021–2030 and established the management and conservation systems for wild germplasm. Meanwhile, China is developing the Regulations on Accessing and Sharing the Benefits of Genetic Resources, aiming to standardize these activities. The recently adjusted List of Key Protected Wild Animals in China strengthened the protection of wild germplasm and the fight against law violations. The update of the List of Key Protected Wild Plants has come to a close and the relevant laws and regulations are being revised.

(2) Biodiversity cataloging. The editing of *Flora Reipublicae Popularis Sinicae* (Chinese version) and *Flora of China* (English version) has been completed. The progress made in the compilation of *Fauna Sinica* and *Cryptogam Flora of China* has greatly improved the knowledge of biodiversity and the development of taxonomy in China. The diversity of species in China has been preliminarily elucidated while a large number of new species are still being discovered and described each year. Taking vascular plants as an example, about 200 (on average) new species were discovered each year from 2000 to 2019 in China [5], accounting for 1/10 of those discovered worldwide. There are still large areas that have been less intensively or uninvestigated in the borders of western and southwestern China, such as southeastern Tibet, southern Yunnan, the karst areas in Yunnan-Guizhou-Guangxi, and northern Xinjiang. The Biodiversity Committee of Chinese Academy of Sciences collects and analyzes the latest data on species with the help of expert review, and compiles the Catalogue of Life China, which is published yearly. On the basis of cataloging species, systematic evaluation of endangered higher plants, vertebrates, and macrofungi in China provides basic data for the conservation of wild germplasm.

(3) *In situ* conservation. The *in situ* conservation of wild germplasm has been improved by the construction of a nature reserve system dominated by national parks. By the end of 2020, there are a total of 11 800 nature reserves in China, which account for approximately 18% of the land area and protect 85% of wild animal populations and 65% of higher plant communities in China [6].

(4) *Ex situ* conservation. The botanical garden system based on the core botanical gardens of Chinese Academy of Sciences has collected and preserved more than 22 000 species of living plants. It is roughly estimated that 60% of native plants are included in *ex situ* conservation [7]. National and local crop germplasm banks/nurseries have collected and stored the wild relative species of crops [8]. The construction and improvement of these facilities play an increasingly important role in germplasm conservation. The Germplasm Bank of Wild Species, built by Kunming Institute of Botany, Chinese Academy of Sciences, is the only comprehensive conservation facility in China that focuses on wild germplasm. By December 2020, the facility had conserved 85 046 plant seed accessions of 10 601 species (36% of the seed plant species in China), 24 100 plant tissue cultures of 2 093 species, 60 262 accessions of 2 203 animal species, and 22 800 strains of 2 280 microbial species. The facility ranks first in Asia in terms of wild germplasm conservation and has achieved the long-term goals of construction set by the National Development and Reform Commission.

(5) Major projects and platforms. Germplasm is the basic material for science/technology innovation and bio-industrial revolution. In addition to continuous standardization, normalization, and targeted collection/conservation of germplasm, resources have been integrated and platforms have been constructed for a shift to openness, sharing, and specific services. In the 20th century, the National Science and Technology Commission (now the Ministry of Science and Technology) realized that the collection, organization, and conservation of germplasm provide important resources and are the prerequisite for scientific research and technological development. Since 1999, the investigation and collection of germplasm in China have been promoted and supported through implementation of special projects for basic research and construction of platforms. Several projects were granted in 2019 and launched in 2020, such as Investigation of Plant Germplasm in Major Marshes and Wetlands in China, Scientific Survey of Wild Plants as Fiber Sources for Light Industries and Textile, Investigation of Wild Economic Plant Resources in Northeast Reserved Forests, and Comprehensive Scientific Expedition of Biodiversity in the Dabie Mountains, all of which involved the investigation, collection, and conservation of wild plant germplasm. In addition, the National Science & Technology Infrastructure, organized under the leadership of the Ministry of Science and Technology, supports the construction of germplasm banks

for important wild plants, crops, forest trees, livestock and poultry, aquatic animals, parasites, and microorganisms, which promotes the strategic focusing, standard development, resource integration, and advantage complementation in related fields. Platforms were established to organize and concentrate the otherwise scattered scientific and technological resources, and to promote the sharing of these resources. For example, relying on the Germplasm Bank of Wild Species, the National Wild Plant Germplasm Resource Center, which focuses on wild plant resources, combines the germplasm banks of 11 scientific and educational institutions in China. At the end of 2020, more than 120 000 accessions of 13 000 species were stored in these banks. The National Resource Center for Non-Human Primates, which was established in 2019 by the Kunming Institute of Zoology, Chinese Academy of Sciences, strengthened the collection and preservation of non-human primate resources such as rhesus macaque and black snub-nosed monkey, enriching the reserves of strategic biological resources and experimental materials in China. The Chinese Academy of Sciences has emphasized on promoting the Strategic Biological Resource Service Network Plan, which aims to build an integrated resource system to better support the development of science and technology. By the end of 2020, 73 germplasm banks/facilities in 40 institutes of Chinese Academy of Sciences had collected 7.35 million pieces of bioresource data, including 640 000 germplasm accessions, which offers a great advantage.

2 Prospect of wild germplasm conservation in China

2.1 Improving the top-down design and overall planning

Strengthening top-down design is a basis to ensure the systematic conservation and future utilization of wild germplasm in China. The construction of agricultural germplasm banks started early and has provided important resources and technical support for China's economic development. Globally, large-scale wild germplasm conservation facilities are mainly distributed in developed countries, which not only rely on their economic power but also reflects their forward thinking and strategic planning of science and technology innovation.

Compared with the germplasm banks in industry sectors, the Germplasm Bank of Wild Species established based on the Chinese Academy of Sciences is a platform for scientific research and strategic resource reserve. Taking the advantage of regional natural resources, this bank mainly focuses on the key scientific issues of China regarding resources, ecology, and biotechnology. The bank aims to enhance the ability of China to implement international conventions to win the initiative in participating or leading international plans, and to provide systematic consultation and a decision-making basis for industry departments and local governments through the enrichment of physical objects, data, and technologies. Therefore, the planning of wild germplasm collection and preservation should be continued on this basis. For the resources with relatively mature conservation theories and technologies and remarkable protection performance, it is necessary to stabilize and enhance the capacity of facilities. For the resources that cannot be preserved on a large scale due to technical barriers, active planning and gradual promotion are needed to establish a quantitative advantage through long-term accumulation. Institutes and botanical gardens affiliated to the Chinese Academy of Sciences in Southwest, Northwest, and Northeast China have long used the regional advantages and made outstanding historical achievements in wild germplasm collection, research, and preservation, with a rich collection of specimens. Based on the current foundation and coordinated planning, they will play a better role as the "national team" for germplasm conservation and investigation.

There are several ongoing large-scale projects on national resource investigation in China, such as the First National Survey and Collection of Forest and Grass Germplasm, the Second Comprehensive Scientific Expedition of the Qinghai-Tibet Plateau, and the Fourth National Survey of Chinese Medicine Resources. In addition to focusing on specific scientific issues, systematic collection and conservation of wild germplasm could be strengthened by these projects to enhance the integrity and cooperativity of germplasm management in China.

2.2 Enhancing the survey and collection projects of wild species and the evaluation of germplasm traits

The collection and conservation of germplasm in China are among the top in the world. Great progresses have been made for the collection and conservation system of wild germplasm. However, there are species that have not yet been recognized in the diverse ecosystems of China and need to be conserved as soon as possible. These are unique and irreplaceable resources evolved in the nature. With the development of related disciplines and the continued exploration of the application value of organisms, survey and collection of wild germplasm should be further expanded to consolidate the leadership of China in strategic germplasm conservation and improve the existing germplasm conservation system. For the collection and conservation of wild germplasm, it is necessary to strengthen the sampling and conservation of different populations of key species, expanding from collection based on background resource catalogues to the survey of resource stocks. For example, relying on the existing national field stations, catalogued wild germplasm and dynamic changes in stock can be included in the basic data for observation. In addition, molecular identification and targeted evaluation of collected germplasm should be bolstered in the

light of major national strategic needs, and the deep exploration and sharing of germplasm should be promoted to accelerate the utilization of such resources.

2.3 Enforcing and implementing laws and regulations on the protection of biological resources

A series of laws, regulations, and department rules regarding genetic resources have been proposed and enacted in China, providing a legal basis for the conservation and utilization of wild germplasm. However, the benefit-sharing system is not defined in the current legislation. As a party to the Nagoya Protocol, China has developed the Regulations on Accessing and Sharing the Benefits of Genetic Resources (Draft) to address the problems of insufficient generation and protection of germplasm intellectual property rights, and the loss of germplasm caused by excessive use, illegal trade, and biopiracy. The draft clarified the management measures for the acquisition, export/import, and benefit-sharing of germplasm/genetic resources. This regulation should be introduced and implemented as soon as possible to make full use of wild germplasm while protecting national strategic genetic resources. Moreover, with the advances of the Belt and Road Initiative, China will fulfill more international obligations and greater responsibilities, making pivotal contributions to the conservation of wild germplasm in countries along the Belt and Road. The introduction of relevant policies and regulations should take into account international cooperation with these countries.

2.4 Promoting cooperation and joint work plans on germplasm management and regulation enforcement

In recent years, the relevant administrative authorities of China have intensified the supervision on wild germplasm. The management and conservation of germplasm have been promoted through ecological and environmental protection inspection and fight against the destruction of wild animal and plant resources. Cooperation with scientific research teams can be further reinforced to increase the scientificity and rationality of supervision and law enforcement. For example, DNA barcoding technology can be used to improve the identification and warning of illegal activities on germplasm.

In terms of national security, the management of wild germplasm export/import will receive greater attention with the globalization of trade and the advance in Belt and Road Initiative. International cooperation of law enforcement for wild germplasm should be strengthened. Law enforcement authorities and scientific research entities can establish cooperation and linkage mechanisms for the export/import of germplasm and reinforce the cooperation and construction of platforms used for inspection or quarantine. While guaranteeing national interests, efforts should be made to separately manage the germplasm used for scientific research and commercialization, simplify the inspection and quarantine procedures for inactivated genetic resources (e.g., exsiccatae and wet specimens), accelerate the customs entry of wild germplasm for scientific research, and reduce the tariffs on such germplasm, which will facilitate the utilization of germplasm from other countries.

2.5 Building talent team to strengthen the management and operation of germplasm facilities

China attaches increasing importance to biodiversity research and strategic germplasm collection. However, the structure of talent teams in germplasm banks remains unbalanced and has clear gaps. The lack of technicians for resource collection and conservation and the outdated knowledge of managers have seriously constrained the innovation and development of germplasm banks. Meanwhile, it is suggested to deepen the reform of the current science and technology evaluation system to objectively reflect the important roles of germplasm banks in implementing national economic development strategies and in providing scientific and technological support and services for sustainable development. The performance evaluation system should be optimized to expand the space for the development of technicians, to ensure stable support for key technical talents in germplasm management and conservation (e.g., classical taxonomy, resource collection and conservation), and to strengthen the training of reserved talents and the construction of support teams.

2.6 Increasing the input on fundamental research and the development of technical standards

Insufficient input in the study of basic theories and technical methods of wild germplasm has constrained the collection, conservation, evaluation, and utilization of germplasm. Research on the mechanisms underlying the degradation or death of wild germplasm should be enhanced to provide a new theoretical basis for germplasm conservation. Meanwhile, it is recommended to expand the application of novel technologies (e.g., seed bank, cryopreservation, and artificial intelligence) in the conservation of wild germplasm, so as to provide new technical routes for effective conservation of germplasm. The development of standards and specifications of generic technologies can be used as an important leverage to improve the quality of germplasm.

2.7 Arising the public awareness on germplasm conservation through training programs

The conservation of germplasm distributed across China is an important part of national security and a specific action for the construction of ecological civilization, which requires the participation of all citizens. In February 2021, the Ministry of Ecology and Environment and other departments jointly released the “Beautiful China, I am the Actor” Action Plan to Enhance Citizens’ Awareness of Ecological Civilization (2021–2025) (hereinafter referred to as the Action Plan) to incorporate ecological civilization into the national education

system. The knowledge and conservation of germplasm should be emphasized and reflected in the subsequent implementation of the Action Plan, and all citizens should be encouraged to participate in germplasm conservation. For instance, the public awareness of germplasm conservation can be improved through national science popularization programs and the relevant research and propaganda campaigns of institutes, zoos, botanical gardens, and reserves. These measures will establish the value of ecological civilization construction, and build a comprehensive national action system for ecological environment governance.

The establishment of China's first wild germplasm bank in 2007 and the collection of seeds from ten thousand species of wild plants demonstrate the remarkable achievements in the conservation of wild germplasm in China. Considering the post-2020 global biodiversity framework and the vision of "Building a Shared Future for All Life on Earth", there is a long way to go for wild germplasm conservation in China. We recommend increasing the input and starting the second-phase construction of wild germplasm banks as early as possible to make the leap from seeds to seed industry. In the meanwhile, it is essential to fortify the existing foundation, develop scientific theories of wild germplasm, and lead the innovation of wild germplasm conservation technologies. These actions will provide strong support for effective implementation of the Convention on Biological Diversity. These activities will also promote the development of bio-industry, the construction of ecological civilization, and the building of a Beautiful China.

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